



APPENDICES TO THE SEVENTH NORTHWEST CONSERVATION AND ELECTRIC POWER PLAN

APPENDIX G: CONSERVATION RESOURCES AND DIRECT APPLICATION RENEWABLES

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OVERVIEW

This appendix provides an overview of the general methodology used by the Council for estimating the conservation resource potential in the region and describes the major sources of information used to prepare that analysis. It also provides a description of the spreadsheet workbooks containing the detailed input assumptions and specific source data used for each of the measures in the Council's conservation supply curves. The workbooks are available on the Council's Seventh Power Plan web site <http://www.nwcouncil.org/energy/powerplan/7/technical>.

The Council structures this work by examining many conservation measures. A conservation "measure" is any device or method that results in electricity savings compared with its baseline. The Council estimates costs and savings for over 1,600 measure permutations.¹ These costs and savings, coupled with savings shape over time, capacity impacts, and estimates of the possible pace of deployment, are used to develop supply curves of conservation potential available by year. The supply curves represent the amount, daily and seasonal shape, and capacity characteristics of conservation available at different cost levels by year. Costs are expressed as TRC (Total Resource Cost) net levelized costs, in 2012 dollars, so they can be compared to the costs of power purchases and the costs of new resource development.² The Council uses an in-house model called ProCost to calculate measure-level TRC net levelized cost, estimate the hourly, daily and seasonal savings, and identify capacity impact of efficiency measures. The levelized cost and savings potential amount, by season and year, and the capacity impacts are inputs to the Regional Portfolio Model.

The Regional Portfolio Model determines the amount of energy efficiency to be developed to achieve least-cost and least-risk adequate electric system for the region. Findings from the Regional Portfolio Model include year-by-year conservation development goals, expressed in average megawatts of energy, to achieve a least-cost and least-risk system. Regional Portfolio Model findings are also used to establish conservation cost-effectiveness methodologies to guide conservation program development. The methodology for cost-effectiveness is based on a benefit-to-cost ratio rather than a levelized cost. The benefit-to-cost ratio provides a means to assure that both the shaped energy and capacity savings of the measures are taken into account.

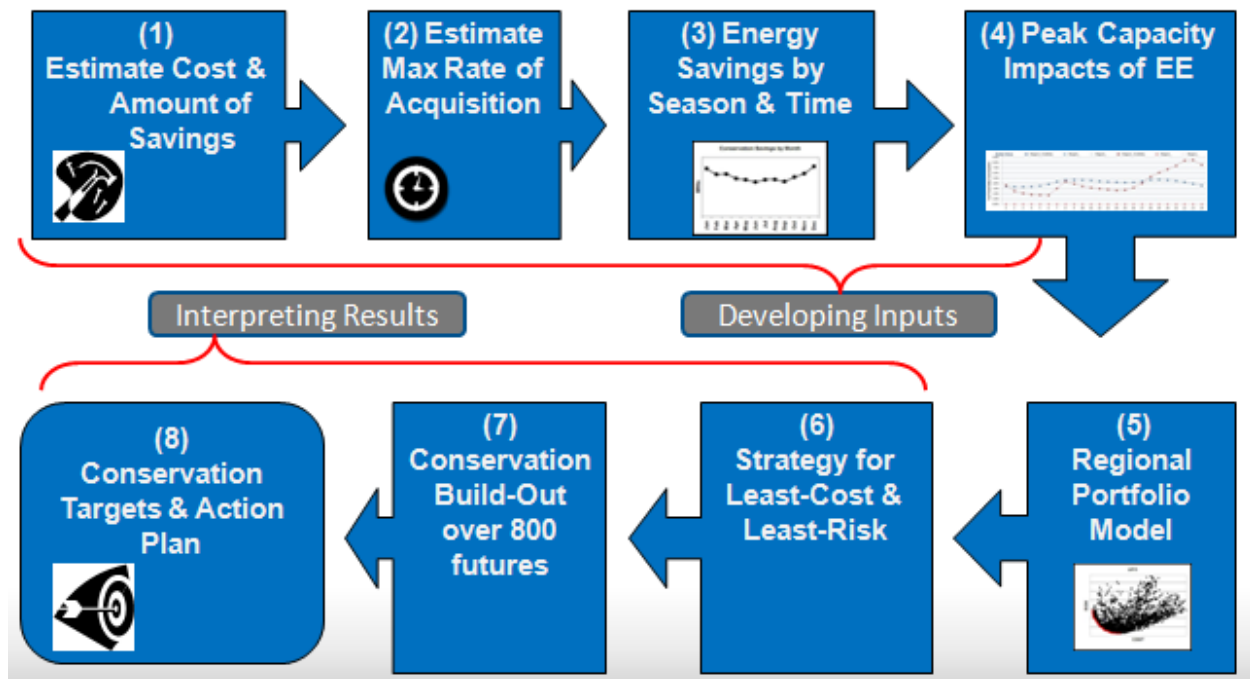
Figure G - 1 describes the overall process. The first tier of Figure G - 1 includes the development of inputs for the conservation assessment which is the subject of this appendix.

¹ A measure permutation includes different applications and different efficiencies for a given measure. For example, a 1.5 GPM showerhead in single family homes with electric water heating is a unique permutation for the low-flow showerhead measure. Other measure permutations would change the segment (multifamily, manufactured), the flow-rate of the showerhead (1.0 GPM), or the water heater type (heat pump water heater).

² "TRC Net Levelized Cost" is computed based on all costs minus all benefits regardless of which sponsor incurs the cost or accrues the benefits. TRC Net Levelized Cost includes all applicable costs and all benefits. In addition to energy system costs and benefits, TRC Net Levelized Cost includes non-energy, other-fuel, O&M, periodic-replacement and risk-mitigation benefits and costs. TRC Net Levelized Cost corresponds to TRC B/C ratios with regard to the costs and benefits included. Benefits are subtracted from costs, and then levelized over the life of the program.

The second tier of Figure G - 1 describes the analysis and process to set the conservation targets for the region. That analysis is described in Chapter 15 and Appendix L.

Figure G - 1: Overview of Council Conservation Analysis and Methodology

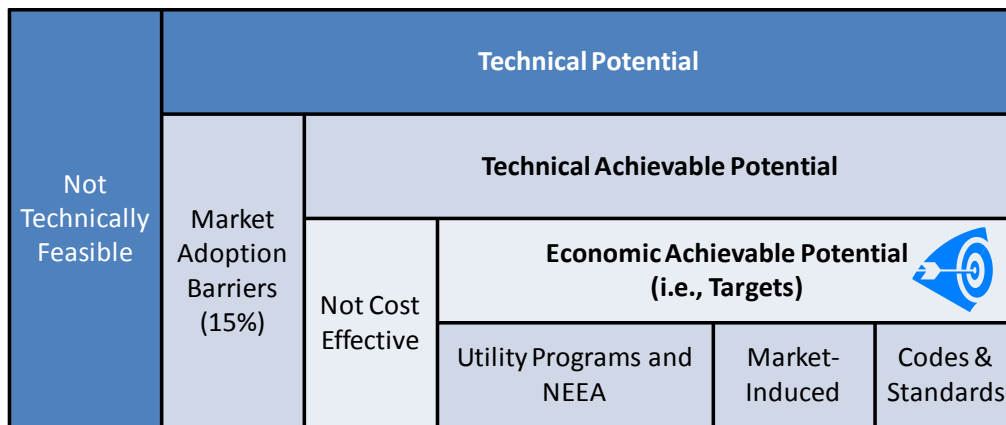


The following sections describe the “global” inputs and methodology used by the Council in its assessment of regional conservation resource potential. Later the appendix describes the conservation cost-effectiveness methodology.

GENERAL CONSERVATION RESOURCE METHODOLOGY

The three types of conservation resource potential considered are Technical Potential, Technical Achievable Potential, and Economic Achievable Potential. An illustrative description of what each represents and their interrelationship is provided in Figure G - 2.

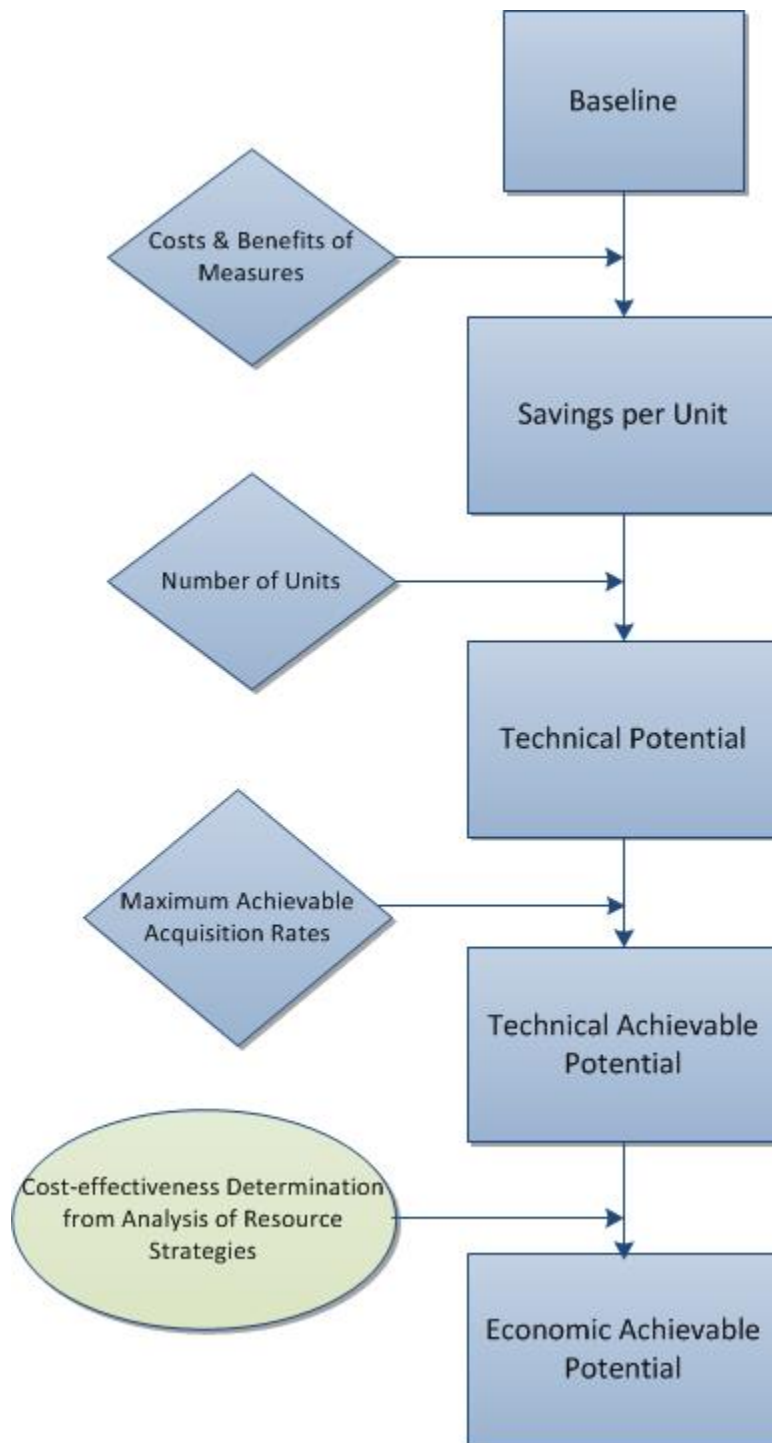
Figure G - 2: Types of Conservation Potential

Adapted from the National Action Plan for Energy Efficiency³

The general methodology for developing the potential is considered a bottom-up method. This means that the total regional potential estimates are built up from individual conservation measures (e.g., efficient light bulbs, motors, refrigerators) multiplied by the number of applicable units in the region. These are then summed by bundle, category, and sector to reach the total regional conservation potential. The overall steps for estimating the different types of potential are illustrated in Figure G - 3. Note that the industrial sector uses a different (top-down) method; see the Industrial Sector section for more information.

³ National Action Plan for Energy Efficiency (2007). *Guide for Conducting Energy Efficiency Potential Studies*. Prepared by Philip Mosenthal and Jeffrey Loiter, Optimal Energy, Inc. <www.epa.gov/eeactionplan>

Figure G - 3: General Methodology to Estimating Potential



Each of these components will be discussed further below.

Baseline

The “baseline” refers to the conditions of the electricity-using buildings, systems, and devices at the start of the plan. For conservation, the baseline is what the energy efficiency is measured against. The baseline estimate is a critical factor in determining both energy savings and forecast energy demand. The Council uses a frozen efficiency baseline forecast described in Chapter 7. Estimates of current market conditions and characteristics of the building stock come from several sources. Key among these are the residential, commercial, and industrial stock assessments completed by the Northwest Energy Efficiency Alliance (NEEA), selected studies from utilities, Bonneville, Energy Trust of Oregon, and other sources.

For new and replacement equipment, baseline conditions are the more efficient of either (1) minimum applicable code or standard or (2) market conditions at the start of the planning period. State building codes and federal and state standards for equipment are continually being upgraded. The baseline assumptions codes and standards used in the Seventh Power Plan are those that were adopted at the end of 2014, with few exceptions. Some of these include standards that were adopted before the end of 2014, but with effective dates that occur in the future. For such codes or standards, both savings estimates and the demand forecast reflect the effective dates of adopted standards. If current market practice is more efficient than code, baselines are generally estimated using the average efficiency as typically taken from available sales data. Lacking sales data, other sources are used such as retail stocking data (such as the California Energy Commission appliance database), ENERGY STAR market share data, distributor sales data, and store shelf surveys. The Council estimates current market practice as of the beginning of 2016. Cost data are from utility program data, US DOE National Impact Assessment workbooks, or on-line retail stores. There is a baseline assumption for each measure in the Council analysis. These baseline assumptions are described in the measure workbooks.

Units

Coupled with the baseline efficiencies are the counts of buildings/systems/devices. In all cases, the number of units is tied to the demand forecast. In development of the forecast (see Chapter 7), the Council projects the total number of units (e.g. households, by state and segment, or commercial square feet, by state and segment) over the 20-year planning horizon. These quantities, multiplied by the saturations and electric fuel shares, give the total number of units available. For example, the number of refrigerators is equal to the number of households times the average number of refrigerators per home. Within the sector-specific sections below, more details are provided on the sources for number of units.

Technical Potential

Technical potential is the amount of conservation that is technically feasible. It considers conservation measures and the number of these measures that could physically be installed, without regard to achievability or cost. It can be viewed as the upper limit of what conservation potential is available.



A conservation “measure” is any device or method that results in electricity savings compared with its baseline. The Power Act defines conservation as “any reduction in electric power consumption as a result of increases in the efficiency of energy use, production, or distribution”.⁴ For a measure to constitute conservation under the Act, it has to meet both parts of the definition. That is, the measure must reduce electric power consumption and the reduced consumption must result from an increase in the efficiency of energy use, production, or distribution. A measure that does just one or the other – for example, reduce electricity consumption but not through an efficiency increase – does not qualify as “conservation” under the Act.

Measures are identified from the range of measures currently in utility programs, as well as a broad search of utility potential assessments, emerging technology research, and input from local, regional, and national experts. Once the measures are identified, Council staff seeks to identify adequate and reliable savings and cost data. Costs and savings are based both on engineering estimates, as well as estimates based on results from the operation of existing programs. Note that although the Council included a wide-ranging list of measures, no conservation assessment can include *all* efficiency measures that could be installed. Some measures were passed over due to lack of data or resources at the time of the supply curve development. The Council believes these omissions do not significantly impact results. A list of known missing measures is provided as part of the discussion about each sector. Also, as described in Chapter 12, there are additional measures only included in the emerging technology scenario, as the Council does not yet consider them currently available and reliable. If a measure is not in the Seventh Power Plan, this does not preclude program administrators from providing incentives for such a measure.

The efficiency measures are grouped into three bundles: new, natural replacement, and retrofit applications. There are three reasons to distinguish these application modes. First, costs and savings can be different by application mode. Second, in the case of new and natural replacement, the available stock for the measure depends on the forecast of new additions and replacement rate for equipment. These opportunities are tracked separately over course of the forecast period and limit the annual availability of conservation opportunities. Third, the Council’s portfolio model treats new and natural replacement applications as lost-opportunity measures that can only be captured at the time of construction or natural replacement.

Measure costs, savings, applicability, and achievability estimates are identified separately for each of the new, natural replacement, and retrofit application modes. The Council analyzes measure costs and savings on an incremental basis. Measure cost is the incremental cost over what would be done absent the measure or program. The same is true for savings. Incremental measure costs and savings can be different depending on the application mode. For example, incremental costs of high performance windows in a new application only include the additional cost of the windows required by code. In a retrofit application, the labor cost of removing and replacing the existing window are added to the measure cost.

⁴ Northwest Power Act, §3(3), 94 Stat. 2698.



Measure applicability reflects two major components: technical applicability and measure saturation. First is the technical applicability of a measure. Technical applicability includes what fraction of the stock the measure applies to. Technical applicability can be composed of several factors. These include the fraction of stock that the measure applies to, overlap with mutually exclusive measures, and the existing saturation of the measure. Existing measure saturation reflects the fraction of the applicable stock that has already adopted the measure and for which savings estimates do not apply. When the baseline is equivalent to the average market conditions, then the measure saturation is set to zero.

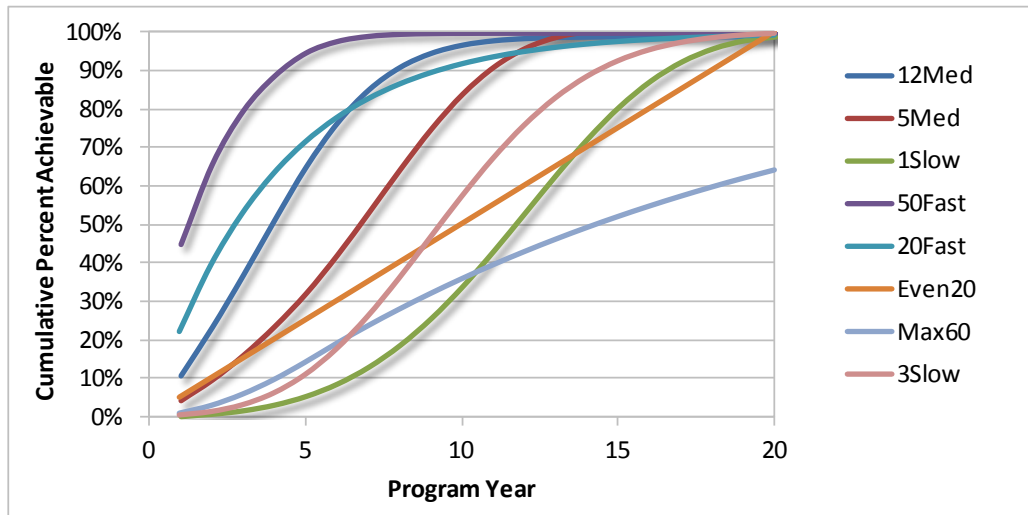
Technical Achievable Potential

The Council assumes that only a portion of the technically available conservation can be achieved. Ultimate achievability factors are limited to 85 percent of the technically available conservation over the twenty-year forecast period.⁵ In addition to a limit of 85 percent, the Council estimates near-term achievable penetration rates for bundles of conservation measures. For these estimates, conservation measures are bundled based on the characteristics of the measures and consideration of the likely delivery mechanisms. In the Seventh Power Plan, the Council uses a suite of typical ramp rates to reflect penetration rates, illustrated in Figure G - 4. For example, measures involving emerging technology might start out at low penetration rates and gradually increase to 85 percent penetration. Measures suitable for implementation by a building code or a federal equipment standard might increase rapidly to 85 percent penetration in new buildings and major remodels. Measures requiring new delivery mechanisms might ramp up slowly. Simple measures with well-established delivery channels, like efficient showerheads, might take only half a dozen years to fully implement. Whereas retrofit measures in complex markets might take 20 years to reach full penetration. The Council also considers region wide conservation program accomplishments when developing these ramp rates to help align early year potential with recent historic accomplishments. Assumptions for the ramp rates applied to each measure are detailed in the conservation supply curve workbooks described by sector below.

⁵ See <http://www.nwcouncil.org/reports/2007/2007-13/> for more information on the source of 85%.



Figure G - 4: Suite of Ramp Rates



Cost and Benefits of Conservation Resources

The Council estimates the cost and benefits of conservation by measure. The Council's analysis attempts to include all quantifiable costs of conservation measures including capital costs, labor and markup, finance costs maintenance, operations-fuel, non-energy consumables, other quantifiable non-energy costs, and program administrative costs. The net cost is the total cost of the measure less any non-electric impacts. Costs represent an increase in the required financial commitment relative to the baseline and are expressed as positive incremental effects. Benefits represent a reduction in the required financial commitment and are expressed as negative incremental effects.

Costs and non-electric impacts are tallied regardless of which sponsors incurs these costs or accrues the benefits. The details of the inputs are provided here. The following section provides an overview of the calculation methodology and ProCost, the tool used by the Council to estimate TRC net levelized cost.

Calculating Levelized Cost

The Council uses a levelized cost to compare conservation resources to supply resources. There are many definitions of levelized cost depending on what components are included. The Council uses the total resource net levelized cost (TRC net levelized cost) for its analysis of the cost of conservation measures, which is similar to the Societal Cost Test outlined in the National Action Plan for Energy Efficiency and the California Standard Practice Manual.⁶ This includes all of the costs and benefits described in the following sections to reflect the full cost of the measures, regardless of who is paying the costs. ProCost is the tool the Council uses to calculate the TRC net levelized cost for conservation measures.

⁶ <http://www.epa.gov/cleanenergy/documents/suca/cost-effectiveness.pdf> and http://www.cpuc.ca.gov/NR/rdonlyres/004ABF9D-027C-4BE1-9AE1-CE56ADF8DADC/0/CPUC_STANDARD_PRACTICE_MANUAL.pdf



The primary components of the TRC net levelized cost are the net present value (NPV) of the measure costs divided by the annual savings of the measure. Economic costs and benefits are converted to present value costs and benefits based the financing costs, sponsor cost shares, and discount rates. ProCost uses standard capital recovery factors and present value (PV) factors to calculate PV costs and benefits. Finance costs use sponsor-specific interest rates and terms as assigned by user input to calculate PV of capital costs of measures. Annual costs and benefits that are not financed are counted in the years they occur and discounted to present values using standard present value factors and the global discount rate of 4 percent used in all Council analysis for the Seventh Plan.

ProCost sums all of the present value costs and nets out benefits. This net present value is then amortized over the life of the program (20 years) using standard capital recovery factors and the discount rate. The resulting annual “levelized” cost is divided by the discounted annual energy savings adjusted for transmission and distribution line losses to produce a levelized cost per unit energy saved in dollars per kWh.

The TRC net levelized costs are all costs minus all benefits regardless of which sponsor incurs the cost or accrues the benefits. In addition to energy system costs and benefits, TRC net levelized cost includes non-energy, program administration, other-fuel, O&M, periodic-replacement benefits and costs. The ten percent Regional Act Credit is taken into consideration in the Regional Portfolio Model and thus not included in the TRC net levelized costs uses in the supply curve inputs. The costs and benefits included in the Seventh Power Plan are summarized on Table G - 1. Each of these parameters is discussed in the following sections.

Table G - 1: TRC Net Levelized Cost Components

Costs Included	Benefits Netted Out
Capital & Labor	Deferred T & D Expansion
Annual O&M	Regional Act Credit*
Program Administration	Deferred Generation Capacity Investment**
Periodic Replacement	Avoided Periodic Replacement
Other Fuel Costs	Other Fuel Benefits
Non-Energy Impacts	Non-Energy Impacts

*The 10 percent advantage for conservation in the Northwest Power Act is accounted for when comparing conservation and other resources in the RPM rather than in the levelized cost of conservation.

** The value of deferred generation capacity is determined as part of the RPM analysis and is not included as part of the levelized cost input to the RPM analysis.

Cost of Conservation

The cost of conservation, as described above, is based on the incremental cost of the measure compared to the baseline case. The Council also includes a programmatic administration cost, approximated at 20 percent of the incremental cost. In addition to those up-front costs, a measure may have on-going operation and maintenance (O&M) costs (or benefits) compared to the baseline. For example, a heat pump water heater has maintenance costs to clean filters and discharge condensate compared to an electric resistance water heater. There may also be periodic replacement costs (or benefits) compared to the baseline. An example of the periodic replacement cost is the replacement of system component that was not present in the baseline system, like a compressor in a heat pump heating system that replaces an electric baseboard heating system. There may also be other fuel costs, such as additional gas heating required

when high-efficiency lighting (that produces less waste heat) is installed. Finally, other quantifiable non-energy costs are also included in the cost calculation if they can be sufficiently quantified. For example, an evaporative cooler might require significant water consumption and associated water costs compared to a vapor-compression system.

Financial Input Assumptions

The present value cost of conservation is determined in part by who pays for it and how it is financed. The Regional Technical Forum (RTF) was asked to provide recommendations on the anticipated “cost-sharing” between utilities and consumers. Staff also developed estimates of the cost of capital and equity used to pay for conservation based on the mix of consumers in each of the major sectors. These costs shares and finance costs are applied to each cost source for each measure at the time they are incurred. .

Table G - 2 through Table G - 6 show the financial assumptions used in the economic analysis of conservation opportunities in each of the five major economic sectors. Each sector table also provides the utility financial assumptions, where the portion of the initial capital cost is shared between the customer, the wholesale electric provider, the retail electric provider, and the natural gas utility. For the Seventh Power Plan, the Council assumes the natural gas utility will not bear any portion of the cost, but is included for completeness. The analysis assumes that end use customers directly pay 35 percent of measure capital cost and all of measure operational and maintenance costs. The cost of capital varies for among residential, commercial, and industrial customers. Financial life is the term over which a sponsor’s share of capital cost is financed. A financial life of one year indicates that portion is expensed, rather than financed. For the Seventh Power Plan, the Council assumed the portion of capital cost paid by Bonneville, the wholesale utility, as well as retail utilities do not finance conservation investments, but expense them each year.

Table G - 2: Residential Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	4.3%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	46%	0%
Sponsor Share of Annual O&M	100%	0%	0%	0%
Sponsor Share of Periodic Replacement Cost	100%	0%	0%	0%
Sponsor Share of Administrative Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		



Table G - 3: Commercial Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	6.8%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	46%	0%
Sponsor Share of Annual O&M	100%	0%	0%	0%
Sponsor Share of Periodic Replacement Cost	100%	0%	0%	0%
Sponsor Share of Admin Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table G - 4: Industrial Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	8.5%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	46%	0%
Sponsor Share of Annual O&M	100%	0%	0%	0%
Sponsor Share of Periodic Replacement Cost	100%	0%	0%	0%
Sponsor Share of Admin Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table G - 5: Agriculture Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	6.8%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	46%	0%
Sponsor Share of Annual O&M	100%	0%	0%	0%
Sponsor Share of Periodic Replacement Cost	100%	0%	0%	0%
Sponsor Share of Admin Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table G - 6: Utility Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	6.3%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	0%	30%	70%	0%
Sponsor Share of Annual O&M	0%	30%	70%	0%
Sponsor Share of Periodic Replacement Cost	0%	30%	70%	0%
Sponsor Share of Admin Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

The analysis assumes three sponsors of measure cost; the end use customer, the wholesale utility, the retail utility. Gas utility sponsorship is not considered in the Council analysis. This analysis uses a discount rate of 4.0 percent, consistent with the all other resources analyzed in the Seventh Power Plan; see Appendix A for more details.

Benefits of Conservation

In addition to the energy saved by conservation, there are several benefits that reduce the cost of conservation. These contributors include: deferred transmission and distribution (T&D) capacity expansion, deferred generation capacity investment, avoided periodic replacement, other fuel benefits, value of non-power system impacts (also referred to as non-energy benefits), and the regional act credit.

The deferred T&D capacity is estimated from the contribution of conservation on winter peak loads, defined as 6 pm on a weekday in December, January, or February. As discussed in Chapter 7, absent energy efficiency, the regional peak demand is growing. By reducing the peak load with efficiency, ongoing upgrades or expansions to the T&D system and associated costs are deferred. The Council used data from eight transmission utilities and eight distribution utilities to estimate this value: \$26/kW-yr for deferred transmission and \$31/kW-year for deferred distribution (both in 2012\$). These inputs are described in the workbooks T+D Costs on the Council's website <http://www.nwcouncil.org/energy/powerplan/7/technical>. The Council recognizes that potential transmission and distribution systems cost savings are dependent upon local conditions.

ProCost has a new calculation for the deferred T&D capacity benefits since the Sixth Power Plan. In the Sixth Power Plan, ProCost used average losses to calculate the conservation T&D benefits, but for the Seventh Power Plan, ProCost was updated to calculate the losses based on the hour when they occur.

There are two types of losses on the transmission and distribution system. The first are no-load/core losses, or the losses that are incurred just to energize the system – to create a voltage available to serve a load. Nearly all of these occur in step-up and step-down transformers. The second are resistive losses, which are caused by friction released as heat as electrons move on



increasingly crowded lines and transformers. Typically, about 25 percent of the average annual losses are no-load or core losses, and about 75 percent are resistive losses.

Losses increase significantly during peak periods. ProCost uses the formula for the resistive losses, I^2R , where “ I ” is the amperage (current) on any particular transformer or distribution line, and “ R ” is the resistance of the wires through which that current flows. While the “ R ” is generally constant through the year, since utilities use the same wires and transformers all year long, the “ I ” is directly a function of the demand that customers place on the utility. Thus, resistive losses increase with the square of the current, meaning losses increase as load increases. Depending on the system load shape, the percentage of generation that is “lost” before it reaches loads is typically at least twice as high as the average annual losses on the system. During the highest critical peak hours (perhaps 5-25 hours per year) when the system is under stress, the losses may be four to six times higher than the average.

ProCost uses the system load shape and the conservation measure load shape to calculate the impact of the measure on system losses, accounting for both the core and resistive losses.⁷

Conservation measures also have a deferred generation capacity value, though the economic value of this is derived from analysis of resource strategies in the Regional Portfolio Model rather than fixed as an input. As such, the economic value of deferred generation capacity was set to zero for the RPM inputs. Instead, the derived economic value of deferred generation capacity is captured in the determination of the plan conservation goals and for setting cost-effectiveness levels for conservation measures and programs. Measure cost-effectiveness methodology is described in the section below titled “Determining the Cost-Effectiveness Limit for Conservation”.

The other benefits of conservation included in the levelized cost calculation include the periodic replacement, other fuel, and quantifiable non-power system impacts. An example of the periodic replacement benefit is a high-efficiency LED light bulb that has a significantly longer life than a baseline halogen bulb. As such, by installing an LED that has a 12-year measure life, the user avoids replacing the halogen bulb five times (every two years).

The other fuel benefits are savings in natural gas or heating oil from, for example, increased insulation levels. The homeowner who has air conditioning and a gas furnace will save electricity in reduced cooling usage as well as saving gas from reduced heating usage by adding ceiling insulation.

In addition, the Council includes the value of quantifiable non-power system impacts. For example, by installing an efficient clothes washer, the homeowner will use less water than the baseline. The value of this water reduction is included as a benefit in the net levelized cost calculation.

Finally, the Northwest Power Act directs the Council and Bonneville to give conservation a 10 percent cost advantage over sources of electric generation.⁸ The Council does this by

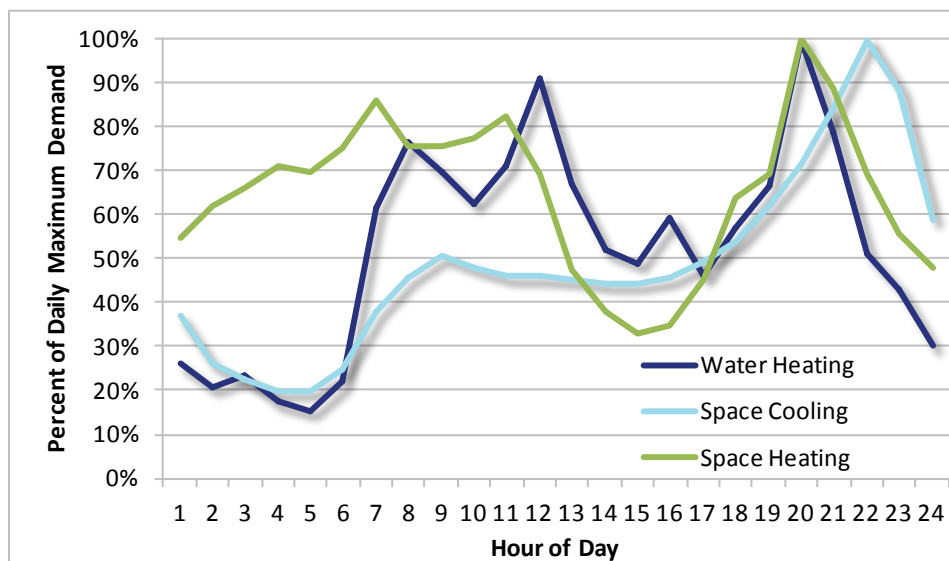
⁷ Overall conservation avoids line losses that range between 7 and 8 percent depending on the load shape of each measure's savings.

calculating the Act credit as 10 percent of the value of energy saved at wholesale market prices, plus ten percent of the value of savings from deferring electric transmission and distribution system expansion, deferred generation capacity investment, and risk avoidance. This credit is applied in the RPM and is thus not included in the TRC net levelized cost input data.

Value of Conservation with Respect to Time

The energy saved from conservation is generally not constant across every hour of the year. For example, efficient street lighting only saves energy from dusk-to-dawn, the hours of which vary over the year. Figure G - 5 shows typical daily load shape of conservation savings for measures that improve the efficiency of space heating, water heating, and central air conditioning in a typical Northwest home. The vertical axis indicates the ratio (expressed as a percent) of each hour's electric demand to the maximum demand for that end use during over the course of the entire day. The horizontal axis shows the hour of the day, with hour "1" representing midnight.

Figure G - 5: Illustrative Hour Load Profile for Three Residential End Uses



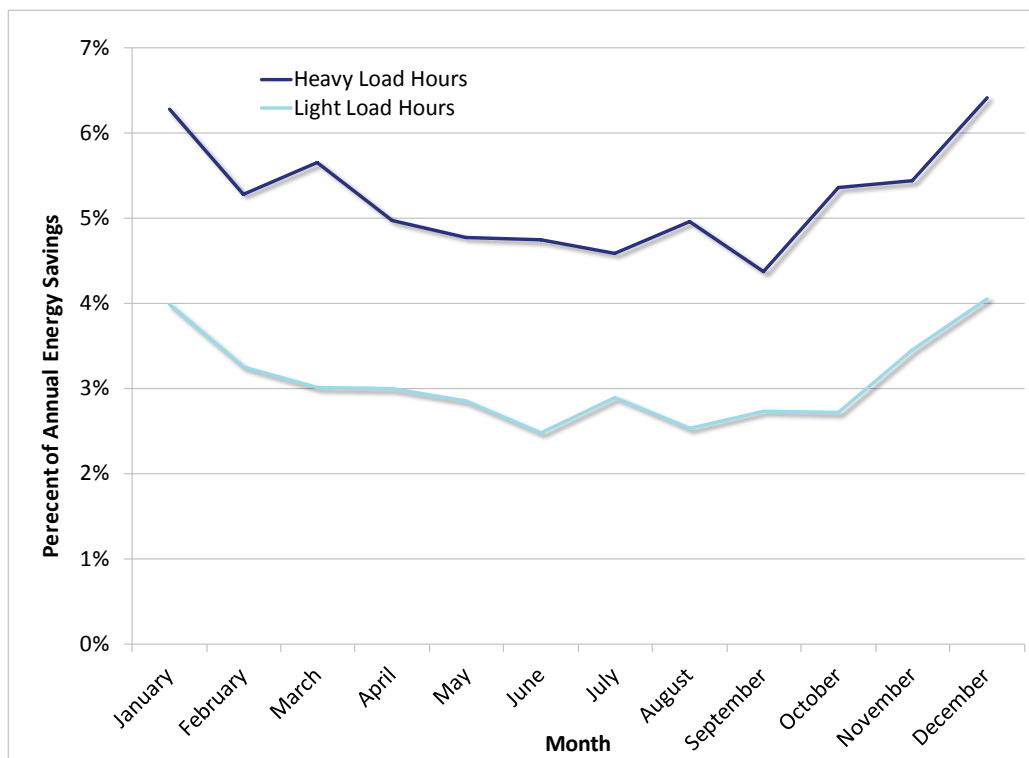
As can be seen from inspecting Figure G - 5, water heating savings increase in the morning when occupants rise to bathe and cook breakfast, then drop while they are away at work and rise again during the evening. Space heating savings also exhibit this “double-hump” pattern. In contrast, central air conditioning savings increase quickly beginning in the early afternoon,

⁸Northwest Power Act, §3(4)(D), 94 Stat. 2699.

peaking in late afternoon and decline again as the evening progresses and outside temperatures drop. Measure savings can also vary seasonally and by day of the week. As the price of electricity varies by day and by season, the value of the conservation will also vary, depending on its savings shape.

The shape of the savings for the complete set of conservation measures in the supply curve during heavy and light load hours is provided in Figure G - 6. As is shown, the energy savings are greater during the winter season than summer, in large part due to significant savings from conversion of electric resistance heating to more efficient heat pump technologies and increased use of lighting during the winter period. As such, the conservation measures have a greater impact on winter peak load requirements than summer peak requirements. Winter peak hours are defined as 6pm on a weekday in December, January, or February. Summer peak hours are defined as 6pm on a weekday in July or August. The peak capacity factor⁹ varied from around 1.2 in summer to around 2.0 in winter, indicating that conservation measures have a fairly significant impact on peak loads, particularly in the winter. Of course each individual conservation measure analyzed by the Council have a unique shape, which will have an effect on its value as a resource option and on measure cost-effectiveness.

Figure G - 6: Monthly Savings Shape for All Measures during Heavy and Light Load Hours



⁹ Capacity factor in this context is defined as the peak savings in megawatts divided by the annual energy savings in average megawatts.

COST-EFFECTIVENESS ANALYSIS METHODOLOGY

The Council uses a multi-step process to evaluate the cost and amount of conservation to be developed for a least-cost and least risk resource strategy. Conservation supply curves are constructed based on cost and savings available from over 1,600 conservation measure permutations across the residential, commercial, industrial, agriculture, and the electric utility system sectors. The conservation supply curves, annual deployment limitations, and the seasonal and time of day availability of conservation data are provided as inputs to the RPM. Data on the cost and availability of generating resource options are also provided to the RPM. The RPM tests plans for the development of conservation and generation resources across 800 different futures. The RPM analysis produces strategies for conservation and generation resource development that have lowest cost and lowest economic risk outcomes for the region. The Council then considers the RPM conservation strategies, along with practical considerations, to develop near-term conservation targets and actions as well as cost-effectiveness guidance for near-term conservation program decisions. The process is outlined in Figure G - 1 above.

As with all other resources, the Council uses the RPM to determine how much conservation is cost-effective to develop.¹⁰ The RPM compares resources, including conservation on a “generic” level. That is, it does not model a specific combined cycle gas or wind project nor does it model specific conservation measures or programs. Run time constraints limit the number of conservation programs the RPM can consider. The RPM cannot consider individual programs for every measure and every specific load shape, and perform a measure-specific benefit-cost ratio for each sub-component of conservation. Therefore, the Council simplifies the set of conservation measures available to the portfolio model. In the case of conservation, the model uses two separate supply curves.

These two supply curves, one for retrofit resources and a second for lost opportunity resources, depict the amount of savings achievable at varying levelized costs. The lost opportunity measures incorporate those that are new or natural replacement applications. The estimates of costs and savings in the supply curves incorporate line loss savings, the value of deferred distribution capacity expansion, and the non-energy costs and benefits of the savings, as discussed above. The available savings are also allocated to heavy and light-load time periods to reflect the time-based value of savings and savings impact on capacity needs.

¹⁰ A full explanation of how the RPM arrives at the cost-effective amount of conservation is described in Appendix L in the section entitled “The Sources of Increased Conservation”.



Decision Rules for Modeling Conservation Resource Acquisition in the Regional Portfolio Model

The reason the RPM uses separate lost-opportunity and retrofit supply curves is that if a lost opportunity conservation resource is not acquired when it is available, it cannot be acquired later (e.g., after the building is constructed) or cannot be cost-effectively acquired later (e.g., the cost of revisiting a home makes adding an increment of ceiling insulation non-cost effective). Thus, the maximum amount of lost opportunity resources is limited annually based on the new construction and equipment turnover. Since retrofit conservation resources do not have this restricted “window of opportunity,” the maximum amount of conservation is limited by the total long-term potential. Deferring the purchase of high-cost conservation resources to periods when market costs are high reduces cost and risk. That is, a portfolio management strategy that acquires high-cost conservation resources early results in higher cost and risk than a strategy that defers their acquisition to periods in future when market prices are higher. If market prices are expected to increase over time, the value acquiring high-cost conservation resource is less in the near-term than in the long term.

The RPM models conservation resources using fourteen¹¹ annual supply curve bins that represent the quantity of technically achievable conservation available each year from 2016 through 2035 at levelized cost. The supply curves are differentiated by levelized cost bin and by retrofit versus lost opportunity resources. The conservation in these cost bins carry with them the shape and capacity characteristics of the combined set of measures in the cost bin. The cost bins, used for both resources are in Table G - 7, along with the average cost and total amount of conservation potential. Note, the RPM can select a portion of conservation within a bin.

Table G - 7: Levelized Cost Bins for Conservation

Bin	Cost Range (2012\$/MWh)	Average Levelized Cost (2012\$/MWh)		Maximum Conservation (aMW)		
		LO	Retrofit	LO	Retrofit	Total
1	<\$20	-\$21	-\$32	959	883	1,841
2	\$20-50	36	36	1,802	1,598	3,400
3	\$50-80	64	65	2,220	1,857	4,078
4	\$80-110	92	94	2,317	2,055	4,372
5	\$110-140	126	125	2,506	2,079	4,585
6	\$140-170	156	160	2,621	2,129	4,750
7	>\$170	580	410	2,818	2,271	5,088

In addition to the numbers presented in the above table there are 38 aMW of potential from short-term lighting savings (pre-2020), all available at less than \$20 per megawatt-hour. This potential accounts for savings between the current baseline and the 2020 lighting standard of 45

¹¹ Seven cost bins for the two resource types (retrofit and lost opportunity)



lumens per watt. Since these savings do not persist past 2020, they are inputted separately from the other conservation measures (they are inputted as a contract purchase).

The amount of conservation resources technically achievable each year increases based on the assumption that programs are able to capture an ever larger share of the available potential over time, as determined by the ramp rates provided in Figure G - 4. The RPM can acquire these technically achievable resources each year up to the quantity it determines to be cost-effective over the full planning period and across the 800 futures tested by the RPM. However, the ramp rate for the measures in a specific cost bin are based on the year in which that bin is deployed in the resource strategy. For example, if bin 4 is deployed in 2020, the achievability for that bin will begin at a low value, based on the *first* year of ramp rate acquisition, or Program Year 1 in Figure G - 4.

The final conservation input into RPM is the capacity value of the savings. Given each conservation measure has an associated savings shape (see Figure G - 5), the contribution of savings during peak hours differs by this shape. For each measure category, the Council calculated the peak contribution for both summer and winter peak hours. The peak contributions, aggregated by levelized cost bin (see Table G - 1), are provided in Table G - 8.

Table G - 8: Peak to energy impact of measures by levelized cost bin.

Bin	Winter Peak Contribution (MW/aMW)		Summer Peak Contribution (MW/aMW)	
	LO	Retrofit	LO	Retrofit
1	1.7	1.4	0.9	1.4
2	1.8	1.4	1.0	1.4
3	1.9	1.5	1.1	1.3
4	1.9	1.6	1.1	1.3
5	2.0	1.6	1.2	1.3
6	2.0	1.7	1.2	1.3
7	2.0	1.7	1.3	1.3

Method for Determining the Cost-Effectiveness Limit for Conservation

Conservation program managers, the Regional Technical Forum, and regulators should use the benefit/cost ratio method outlined below to determine cost-effectiveness. This method assures that all the costs and benefits are captured, that the time-dependent shape of the savings are accounted for, and that the capacity contribution of the measures are fully taken into account. Individual entities may have differing input values than the ones presented below, given specific needs, but the methodology to estimate these parameters should be consistent. If a measure's benefit to cost ratio, from a total resource cost perspective, is greater than one, the measure is

considered cost-effective. This ratio is calculated as follows, where all parameters are in constant dollar value¹²:

$$\frac{\text{Benefit}}{\text{Cost}} = \frac{NPV(\text{energy} + \text{capacity} + \text{other fuel} + NEI + \text{avoided periodic replacement})}{NPV(\text{capital cost} * (1 + \text{admin}) + \text{annual O\&M} + \text{other fuel} + NEI + \text{periodic replacement})}$$

Where *NPV* is the net present value and:

$$\text{energy} = kWh_{i,bb} * ((MP + C)_i + RMC) * (1 + 10\%)$$

and

$$\text{capacity} = kW_{peak,bb} * (T_{avoid} + D_{avoid} + Gen_{avoid}) * (1 + 10\%)$$

The terms are defined as:

NEI = non-energy impacts

admin = administration cost adder (assumed 20%)

kWh = energy saved by time segment *i* (e.g. heavy/light load hours, monthly)

kW_{peak} = winter peak power saved

bb = busbar

MP = market price forecast (\$/kWh) by time segment *i*

C = carbon cost forecast (\$/kWh) by time segment *i*

RMC = risk mitigation credit for stochastic variation in inputs (\$/kWh)

T_{avoid} = deferred transmission capacity credit (\$/kW-yr)

D_{avoid} = deferred distribution capacity credit (\$/kW-yr)

Gen_{avoid} = deferred generation capacity credit (\$/kW-yr)

10% = Regional Act conservation credit

¹² In actuality, the formulation for the benefit-to-cost ratio is more complicated than this equation represents as the costs and benefits represent a stream of values over time. More details are provided in the ProCost users manual.

Other terms were discussed in the section on calculating levelized cost above and shown in Table G - 1.

This analysis is done in ProCost, which captures all the parameters in the formula above. In preparing the inputs for the RPM, the Council estimates the total resource net levelized cost for the measures that includes many of the parameters of the above formula. However, it does not include the deferred generation credit nor the dollar value of the energy savings. The deferred generation credit was included after RPM findings highlighted the region's need for capacity resources. For this analysis, the Council determined the best estimate for this parameter is the discounted cost for the marginal generation resource that would have been built in absence of conservation.¹³ The best fit resource for the *region* is an Aeroderivative simple-cycle combustion gas turbine (SCCT), with a levelized cost of \$190 per kilowatt-year.¹⁴ Given that the conservation target is sufficient to approximately offset the build of a SCCT each year, the value of Gen_{avoid} is the annual deferred cost of this SCCT. In calculating this amount, the Council recognizes that SCCT take approximately three years to build once the decision is made; i.e., the first year in the plan horizon that such a generator could be built is 2019. The resulting deferred generation credit is \$115 per kilowatt-year. Even though the measure energy savings are known, the total dollar value of these energy benefits is not known *a priori*; it is determined through the RPM findings. While the RPM uses a wide range of market prices, determined stochastically, it would be untenable to calculate each measure's cost-effectiveness on a range of market prices. Instead, the Council chooses the base price forecast for this analysis determined using the avoided marginal dispatch cost estimated in the RPM. This value is a result of each RPM scenario, and reflects the variable cost of dispatching the marginal in-region resource.¹⁵ The market price includes two segments (heavy and light load hours) for each time period (monthly). This time variance of market price provides more value to measures that save energy during higher price periods (generally, heavy load hours in the winter). This is described more fully in the section "Value of Conservation with Respect to Time". In addition, the Council will use the Interagency Working Group's estimate of the social cost of carbon at the three percent discount rate.¹⁶ The Seventh Power Plan's Scenario 2B incorporates this carbon damage cost. The Council thus used the expected avoided marginal dispatch cost out of RPM from Scenario 2B that incorporates this cost in dollars per metric ton of carbon dioxide as well as the heat rates associated with the system (to convert to dollars per megawatt-hour). In other words, $MP + C$ becomes a single price stream.

The final parameter is the risk mitigation credit, represented as the *RMC* factor in the energy benefits formula above. Because the Council uses the data from the RPM, a stochastic model with 800 futures run across a number of scenarios to determine the conservation target, the Council uses the risk mitigation parameter to approximate the value of conservation in reducing risk across all of the future unknowns. In other words, there is a premium to purchasing

¹³ Without a robust capacity market in the Northwest, the Council determined the cost of new generating resource is a good proxy for the long-run cost of capacity.

¹⁴ See Appendix H for more information on Aeroderivative gas turbines.

¹⁵ This price could be estimate by the market price out of Aurora^{XMP}, but accounting for the regional resource builds, including conservation.

¹⁶ More information on this estimate if provided in Chapter 15.



conservation to avoid more expensive resource development across the range of futures that is not represented from a single market price forecast used in ProCost or load forecast used to determine the supply curve inputs. The risk mitigation parameter is estimated so that the potential from all cost-effective measures (the economic achievable potential) is nearly equivalent to the conservation targets.

For the Seventh Power Plan, the Council finds that a *RMC* of \$0 per megawatt-hour is needed to achieve the targets provided in Chapter 4, Action Plan, item RES-1. In other words, adding in the deferred generator credit is sufficient to encompass the value of conservation in offsetting system risks. In addition, if the Council had chosen not to include carbon damage cost in the market price, the *RMC* would have been non-zero, around \$25 per megawatt-hour.

Table G - 9 shows the regional achievable savings by sector and major measure bundle derived using a cost-effectiveness limit as calculated above, using the base market price and load forecasts. Savings are shown for the near term (2021), mid-term (2026), and for the entire period covered by the Seventh Power Plan (through 2035).

The purpose of Table G - 9 is to show the major sources of energy efficiency identified in the Council's Seventh Power Plan. It is not intended to dictate either the measures or the pace of their acquisition to be included in utility or system benefits charge administrator programs.



Table G - 9: Estimated Cost-Effective Conservation Potential in Average Megawatts 2021 and 2035

Measure Bundle	aMW by 2021	aMW by 2026	aMW by 2035	Description of Bundle
Residential				
Heat Pump Water Heater	9	62	267	Efficiency factor of 2.0 or greater
Behavior	17	38	45	Reduction in home energy usage through improved controls
Computers and Monitors	32	33	36	Efficient Desktop PC and Efficient Monitor
Heat Pump Upgrades & Conversions	7	26	77	Space heating conversion from electric resistance to heat pump and to heat pumps above the federal standard
Duct Sealing	21	29	30	Sealing existing ducts to <10% leakage
Residential Appliances	11	32	68	Clothes Washer, Dishwasher, Microwave
Advanced Power Strips	29	117	185	Reduction in stand-by energy use of peripheral electronics equipment
Weatherization	121	169	180	High performance windows, insulation
Ductless Heat Pump	29	79	166	Converting zonal electric heating or electric forced air furnaces to ductless heat pumps
Lighting	174	372	463	LED lamps
Showerheads	67	100	121	2.0 gallons per minute or lower flow rate
Other Residential Measures	14	48	96	Includes aerators, WIFI thermostats, HVAC commissioning, heat recovery ventilation
All Residential Measures	530	1,104	1,734	
Commercial				
Advanced Rooftop Controller	22	83	117	System for controlling rooftop HVAC systems (rooftop units)
Bi-Level Stairwell Lighting	1	4	9	
Clothes Washer	0	2	4	
Commercial EM	41	59	65	Improved control of existing systems (energy management)
Compressed Air	5	9	17	
Cooking Equipment	6	23	63	Ovens, steamers, hoods, sprayers, holding cabinets and other kitchen equipment

Appendix G: Conservation Resources and Direct Application Renewables

Measure Bundle	aMW by 2021	aMW by 2026	aMW by 2035	Description of Bundle
Embedded Data Centers	55	230	261	
Direct Control Ventilation Parking Garage	8	12	13	
Direct Control Ventilation Restaurant Hood	6	8	8	
Demand Control Ventilation	12	17	18	
Desktop	13	28	56	ENERGY STAR desktop computers
DHP	12	43	60	Ductless heat pumps in commercial applications
ECM-VAV	4	12	30	Efficient motors in VAV applications
Economizer	18	26	26	Rooftop economizer improvements
Exterior Building Lighting	59	126	142	
Grocery Refrigeration Bundle	37	52	57	Grocery store refrigeration measures
Laptop	0	1	4	ENERGY STAR laptop computers
Light Emitting Capacitor Exit Sign	4	9	19	
Lighting Controls Interior	2	6	13	Interior lighting controls
Low Power LF Lamps	14	39	39	
LPD Package	123	234	428	Interior lighting measures based on lighting power density reduction
Monitor	6	12	24	
Motors Rewind	2	4	5	
Municipal Sewage Treatment	14	32	35	Measures for municipal sewage treatment facilities
Municipal Water Supply	5	11	12	
Parking lot Lighting	6	8	8	
Premium Fume Hood	0	1	4	
Pre-Rinse Spray Valve	1	1	1	
Secondary Glazing Systems	1	5	10	
Showerheads	3	4	4	

Appendix G: Conservation Resources and Direct Application Renewables

Measure Bundle	aMW by 2021	aMW by 2026	aMW by 2035	Description of Bundle
Smart Plug Power Strips	30	42	47	
Street and Roadway Lighting	30	57	61	
VRF	5	25	78	Variable refrigerant flow systems
Water Cooler Controls	2	10	12	
WEPT	3	7	7	Web-enabled programmable thermostats
Water Heater Tanks	0	1	2	Efficient water heater tanks
All Commercial Measures	554	1,242	1,761	
Industrial				
Compressed Air	12	16	18	Efficient equipment and system optimization across all industries
Energy Project Management	37	79	87	Multiple-system energy management, tracking and reporting in large facilities
Fans	26	54	60	Efficient equipment and system optimization across all industries
Refrigeration in Food Processing	9	12	14	Refrigeration equipment and system optimization
Controlled Atmosphere and Refrigeration in Food Storage	43	61	67	Refrigeration equipment and controlled atmosphere system optimization
Clean Room HVAC Systems in Hi-Tech	8	13	15	Industry-Specific Processes: Clean rooms and production facilities
Integrated Plant Energy Management	23	42	77	Top tier whole plant optimization in large facilities
Lighting	32	41	45	Lamp, ballast, fixture and control improvements across all industries
Material Handling	12	27	30	Efficient equipment and system optimization across all industries
Arc Furnaces in Metals	0.1	0.1	0.2	Industry-Specific Process: Arc furnace
Motors	0.0	0.0	0.0	Efficient motor rewinds across all industries
Pulp Screening and Effluent Treatment in Paper	3	5	10	Industry-Specific Process: Pulp screening, effluent treatment
Plant Energy Management	27	38	41	Multiple-system O&M in large facilities

Appendix G: Conservation Resources and Direct Application Renewables

Measure Bundle	aMW by 2021	aMW by 2026	aMW by 2035	Description of Bundle
Refiners and Effluent Treatment in Pulp	3	5	8	Industry-Specific Process: Effluent treatment, refiners
Pumps	42	74	81	Efficient equipment and system optimization across all industries
Material Handling, Drying and Pressing in Wood Products	8	17	19	Industry-Specific Process: Material handling, drying, pressing
All Industrial Measures	284	485	571	
Agriculture				
Irrigation Hardware System Efficiency	32	52	68	Leak reduction, lower pressure delivery, pump & system efficiency
Irrigation Water Management	23	30	41	Scientific irrigation scheduling and low elevation spray application
Irrigation Motor	2	3	3	VFD motors for water pumping
Dairy Efficiency Improvement	0.5	1.1	1.2	Refrigeration, Lighting and motor improvements
Outdoor Lighting	5	7	7	LED lighting for barns
All Agricultural Measures	63	93	121	
Utility Distribution				
Reduce system voltage	12	34	83	Reduce system voltage w/ LDC voltage control method
Light system improvements	7	20	50	VAR management phase load balancing, and feeder load balancing
Major system improvements	8	22	55	Voltage regulators on 1 of 4 substations, and select
All Utility Distribution Efficiency Measures	28	77	187	
All Sectors				
Total	1,459	3,001	4,374	